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Bundesforschungsanstalt Bibliothek für Fischerei, Hamburg

ICES STATUTORY MEETING 1993

C.M. 1993/L:28 Ref.J
Biological Oceanography Committee/Ref. Baltic Fish Committee

PRODUCTION OF HYDROBIONTS AND STRUCTURE OF FOOD GRID WITHIN THE ECOSYSTEM OF THE VISTULA BAY IN THE BALTIC SEA

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ABSTRACT

Energetics of the Vistula Bay ecosystem is estimated based on observations made by the authors in the northern Vistula Bay occupying the intermediate position between the freshwater and sea bodies of waters. The hydrobiont community is represented by euryhaline species: phytoplankton - 78, zooplankton - 46, benthos - 40, fish - 25. A group of species resistant to environmental changes has been distinguished.

Main biomasses during the vegetation season were: 6.2(8.7kJ), of phytoplankton, 2.5(5.2 kJ) of zooplankton, 26.1(78.3kJ) g m^{-2} of benthos. Yield of aboriginal fish amounted to 1.4 tons km^{-2} (60 kJ m^{-2}).

Annual primary production was 12382, effective - 9870, pure - 3870; zooplankton and benthos production during vegetation period amounted to 330 and 1000 kJ m^{-2}, respectively. Ratios of production of planktonic crustaceans, benthos and fish catch to primary production were 2.7, 8, 1 and 0.05 %, respectively.

Rations of planktonic crustaceans constituted 1000 kJ m^{-2} of bottom invertebrates - 3000 kJ m^{-2} and of fish - 18 kJ m^{-2}. Hydrobionts of the Bay are characterized by a relatively short food chain and narrow food spectrum. Yield of aboriginal fish is formed mainly due to detritus food chain.

INTRODUCTION

The hydrological regime of the Vistula Bay places it between the freshwater and sea bodies of water where the salinity fluctuates between 0.3 and 8.3 ‰. The total area is 838 km^2 of which 472 km^2 are within the limits of Russia. The water exchange with the Baltic Sea occurs through the strait 400 m wide. The mean depth of the strait is 2.7 m (Gidromet. ..., 1971).

The Bay plays an important role in the fisheries. The Baltic herring (Clupea harengus membras), bream (Abramis brama), pike-perch (Stizostedion lucioperca) and eel (Anguilla anguilla) are caught there, the mean long-term catch from the Russian part of the Bay constituting 8150 tons (92 % of total catch is made of the spawning part of the Baltic herring population). The catch of the aboriginal fish amounts to 680 tons, the proportion of the bream being 320 tons, of the pike-perch - 200 tons and of the eel - 100 tons. The fish yield with regard to the Baltic herring is 17.2 and for the aboriginal fish - 1.4 tons km^{-2}.

The studies in the Vistula Bay have been carried out since the beginning of the XXth century. After the World War II, the research was resumed by the Russian and Polish scientists. The Laboratory of Estuaries of the AtlantNIRO has accumulated extensive materials. In the present report an attempt is made to summarize the available data and to estimate the Bay energetics.

MATERIALS AND METHODS

Considered are the observations made by the authors over the 1974 to 1992 period in the Russian part of the Vistula Bay. The sampling was made at 9 stations regularly occupied in the Bay area. Nansen bottles (phytoplankton), 101.Vovk plankton grab (zooplankton), Petersen dredge with the coverage area of .025m^2 (benthos) and the small mesh bottom trawl (sampling for the fish feeding studies) were used as fishing gears. A total of 270 samples of primary production, 500 samples of phytoplankton, 920 samples of zooplankton, 560 samples of benthos and 6000 samples for the fish feeding studies has processed. The plankton was collected horizontally at 1 m interval during the vegetation period.

The samples were processed using generally adopted methods: the Gensen's method was used for the plankton and benthos estimation, the "length-weigth" regressions for plankton biomass estimation and the quantitative-weighing method for determination of the food mass weight and its composition. Primary production was estimated by the bottle method in the oxygen modification, and the secondary production by the cohort method. The rations of the invertebrates and the fish were determined from the energy balance (Winberg, 1956) and diurnal feeding rhythm values (Elliott, Persson, 1978, Krasnoper, 1984).

RESULTS AND DISCUSSION

The community of the Vistula Bay hydrobionts has been formed under the influence of the variable salinity gradient and is represented by the freshwater and marine euryhaline species: phytoplankton -78, zooplankton - 46, benthos - 40, the fish - 25. A group of species resistant to changes of the environmental conditions has been distinguished. During the years differing in hydrological regime, a stable main body of organisms was observed against the background of reducing numbers of the species other than the "kernal" species. Seasonality as regards the plankton is expressed be the availability of seccessions and seasonal groups (fig. 1).

During the recent 20-30 years certain changes took place in the composition of predominant phytoplanktonic forms. The species of the genera Pandorina, Eudorina and Volvox common in the fifties (Szarejko, 1953) were missing while the abundance of the bluegreen algae increased. New species of rotifers appeared in the zooplankton including Brachionus urceus, the indicator of α-mezosaprob.

The seasonal dynamics of the phyto-, zooplankton and benthos is characterized by the maximums in April-May and August-September. The zooplankton and benthos maximums are preceeded by those of the phytoplankton (fig.2).

The bulk of the phytoplankton biomass is made of the bluegreen algae, Gomphosphaerium lacustris, of the zooplankton biomass - of the copepods, Eurytemora affinis, and of the benthos biomass; - of the chironomids, Chironomus plumosis f.l. semireductus.

Over the vegetation season, the mean values of the phytoplankton biomass amounted to 6.2 (8.7 kJ), of the zooplankton biomass to 2.5 (5.2 kJ) and of the benthos biomass to 26.1 (78.3 kJ) g m^{-2} (tables 1-3).

A smaller cell volume in terms of morphology is a peculiar feature of the Vistula Bay phytoplankton. A close relationship of the zooplankton and zoobenthos biomass values, and the temperature and salinity of the water was revealed (Krylova, 1987; Naumenko, 1992).

In the plankton and benthos distribution in the Bay area, the abundance and biomass of the phytoplankton, Cladocera, chironomids and oligochaets increase with moving away from the strait connecting the Bay and the Baltic Sea. With the copepods, polychaets and mollusks this process is of opposite direction.

The processes of primary production in the Bay are relatively stable even throughout the years differing in hydrological regime (1974-1976). Two maximums of the photosynthesis recorded were in May and August. The summer maximum is 1.5-2 times greater than that in spring. The annual primary production (A) is 12382 kJ m^{-2} and the effective primary production constitutes 9870 kJ m^{-2}. On the average, 1.3 g of oxygen is spent for destruction during the vegetation season at the mean daily P_p = 1.6 g O m^{-3} and the time of turnover of about three days (table 1). From the total annual data, the process of primary production of the substance and the process of destruction (R) can be described by the ratio:

$P_p = 0.25A$, $R = 0.75A = 2.99P_p$.

With the primary production volume, the Vistula Bay can be related to eutrophic bodies of water (Winberg, 1960).

Processes of secondary production also have two maximums, one in spring and the other in summer-autumn. Over the vegetation season, the zooplankton production (P_z) made up 330, and that of the benthos (P_b) - 1000 kJ m^{-2} (tables 2 and 3). Ecological indices of the growth efficiency (K_2) and specific rate of production (C_1) were 0.47 and 0.31 day^{-1} for zooplankton. Annual P/B were 8.5 for chironomids, 3.9 for oligochaets, 11.0 for polychaets and 1.4 for molluscs. Mean vegetation ratios are : $P_z : A = 2.7\%$, $P_z : P_e = 33\%$, $P_b : A = 8.1\%$, $P_b : P_c = 10.1\%$. The ratio of predatory to non-predatory planctonic crustacean biomass is approximately 40 %.

UTILIZATION OF PLANKTON AND BENTHOS BY VISTULA BAY HYDROBIONTS

Zooplankton. The ration of the phytoplankton-eaters consists of the algae and detritus. For the predators, in addition to the invertebrates (rotifers, young copepods, protozoans), the algae and detritus play an important role. The planktonic crustacean community consumes 1000 kJ m^{-2} over the vegetation season. The ratio of the crustacean ration to the primary production is 8,2 % and to the effective production - 10,2 %.

Benthos. The chironomids, oligochaets, polychaets and molluscs mainly belong to phytodetritus-eaters. The bottom invertebrate ration is 3000 kJ m^{-2} over the vegetation season an average. The ratio of this ration to the primary production is 24.2 % and to the effective production - 30,4 %.

The fish. The young Baltic herring , pike-perch and the other fish as well as the Baltic lake smelt (Osmerus eperlanus m. spirinchus) the main plankton-eaters, feed on the zooplankton (Janchenko, 1982, 1988). The zooplankton is missing from the commercial size fish diet.

The benthos-eaters (bream, silver bream and pope) feed on the chironomids and the roach eat molluscs. In addition to chironomids, the diet of the eels includes the mysids and polychaets. The fish is an occasional food item (Khlopnikov, 1988). The perch and razorfish are facultative predators, the pike-perch older then 2 years are typical piscivorous their fingerlings and the-youngs-of-the-year feed on the mysids and fry (fig.3).

Daily rations of the commercial size fish range from 1.2 to 3.2 % of wet body weight. The largest rations have the roach who consume the low-calorie food, and the eels who intensively accumulate the fat. The pike-perch have the smallest ration the food calorie of which is approximately twice that of the benthos-eaters.

The value of the food eaten out by the fish biomass annually exempted by the fishery is: 4.4 (12.2 kJ) for the benthos-eaters, 0.2(0.8 kJ) for facultative piscivorous and 1.3 (5.4 kJ) g m^{-2} for the pike-perch (table 4).

The ratio of the benthos-eater ration to benthos production is 1.2 %.

The obtained rations show that the energy trasport from the primary producers to the ultimate link (catch of the fish) in the Vistula Bay mainly takes place via the detritus food chain (fig.4). The benthos eating fish make up approximately 70 % of the total catch of the aboriginal fish species. The peculiarity of the energy transport via the pasture chain lies in the fact that the plankton eating fish do not form the fish yield: the main zooplankton-eaters-the young Baltic herring - make up the basic yield in the Baltic Sea. The Baltic lake smelt are the only plankton-eaters in the Bay, however, their abundance is small, and they are not of commercial importance. The predators make up 30 % of the fish yield, 50 % of their ration being represented by the Baltic herring, 40 % by the Baltic lake smelt and the young fish of the other species, and 10 % by the pope. Thus only 40 % of the predatory fish production is formed due to the pasture chain.

The fish catch to primary production ratio indicates the efficiency of the substance utilization in a water body (Winberg, Buljon, 1981). For the Vistula Bay, this ratio was 0.05 %. Such a small per cent of the catch can be attributed to the fact that the pelagic food chain in the Vistula Bay is mainly used for formation of the Baltic herring recruitment and actually does not contribute to the fish yield of the Bay.

CONCLUSIONS

1. The Vistula Bay phytoplankton is represented by 78 species. A small cell volume, $20\,\mu m^3$ on average, is its peculiar feature. The bluegreen algae predominate. The annual primary and effective production are 12380 and 9870 kJ m^{-2}, respectively. Destruction to production ratio is described as $R = 0.75\ A = 2.99\ P_p$. Two maximums of photosynthesis - in spring and summer - are observed.

2. The zooplankton is represented by 46 species, with the copepods of marine origine prevailing. Over the vegetation period, the biomass was 2.5 g m^{-2} (5.2 kJ m^{-2}) and the production - 330 kJ m^{-2}. The phytoplankton maximums are followed by two biomass and production maximums. The zooplankton to phytoplankton production ratio was 2.7, and to effective phytoplankton production - 3.3 %.

3. The benthos is represented by 40 species with the chironomids as the bulk of its biomass. The biomass reaches 26.1 g m^{-2} (78.3 kJ m^{-2}), and the production - 1000 kJ m^{-2} over the vegetation period. Two recorded biomass and production

maximums coincided with the zooplankton maximums. The benthos to phytoplankton production ratio was 8.1, and to effective phytoplankton production - 10.1 %.

4. The Vistula Bay ecosystem is characterized by having the substance and energy transformed into the fish yield via the detritus food chain. Only 10-15 % of the fish yield is formed due to the pasture food chain, the rest 85-90 % resulting from the detritus chain. The pasture chain forms the commercial fish recruitment mainly represented by the Baltic herring. The ratio of the annual catch of the aboriginal fish to the phytoplankton production is 0.05 %.

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Table 1.

Indices of primary production in the Vistula Bay
(N - abundance, bill.cells m^{-3}; B - biomass, g m^{-3};
P_p - pure primary production, kJ m^{-3} $month^{-1}$;
C_b - specific rate of production, day^{-1},
C_a - specific rate of assimilation, day^{-1};
K_2 - index of the growth efficiency)

Month	N	B	P_p	C_b	C_a	K_2
I	29.2	0.8				
II	29.2	0.6				
III	67.4	2.2	616.3	0.6	0.8	0.76
IV	25.4	2.0	511.2	0.8	1.5	0.40
V	55.5	2.0	836.4	0.8	1.2	0.58
VI	113.2	2.3	766.8	0.8	1.3	0.54
VII	273.8	3.5	484.2	0.4	0.7	0.68
VIII	337.0	2.8	1364.6	1.1	1.6	0.76
IX	285.3	2.4	852.0	0.8	1.4	0.42
X	379.9	1.4	308.1	0.5	0.8	0.46
XI	43.0	1.0	85.2	0.5	0.5	0.25
XII	44.3	1.0	31.2		0.3	
$\bar{X}$	140.3	1.8	585.6	0.7	1.0	0.54

Table 2.

Indices of zooplankton production in the Vistula Bay
(N - abundance, thous.sp.m^{-3}, B - biomass, g m^{-3},
R - destruction, g m^{-3} day^{-1})

Month	N	B	C_b	R /B	K_2
IV	255.8	0.92	0.22	0.16	0.52
V	272.2	1.80	0.33	0.27	0.51
VI	202.2	0.63	0.33	0.36	0.43
VII	89.0	0.49	0.40	0.43	0.46
VIII	91.6	1.22	0.33	0.37	0.42
IX	62.6	0.76	0.25	0.34	0.41
X	40.4	0.55	0.08	0.24	0.24
$\bar{X}$	144.5	0.91	0.31	0.31	
m^{-2}	393.1	2.46	0.31	0.31	0.47

Table 3.

Indices of benthos production in the Vistula Bay (B - biomass, P_t - production, g m^{-2}moth^{-1})

Month	B	P_b	P/B
IV	31.1	6.5	0.2
V	21.8	58.9	2.7
VI	20.9	29.3	1.4
VII	25.4	106.7	4.2
VIII	35.2	12.3	0.4
IX	25.0	57.5	2.3
X	23.0	62.1	2.7
$\bar{X}$	26.1	47.6	2.0

Table 4

Rations and proportion of food base eaten out by the Vistula Bay fish

Fish species	Ration		Food base eaten out, year	
	daily, % of wet body weigt	annual, kJ/sp.	g m^{-2}	kJ m^{-2}
Bream	1.6	8545	2.7	7.9
Eel	2.6	7180	1.2	3.5
Roach	3.2	4650	0.5	0.8
Razorfish	1.8	6470	0.1	0.4
Perch	1.6	4030	0.1	0.4
Pike-perch	1.2	17820	1.3	5.4

FIGURE LEGENDS

Fig. 1. Planktocene structure in the Vistula Bay.
1 - main body; its sesonal groups; 2 - spring structure; 3 - summer structure; 4 - autumn structure; 5 - winter structure.

Fig.2. Seasonal dynamics of the Vistula Bay plankton and benthos: Definitions; 1 - phytoplankton; 2 - zooplankton, 3 - benthos.

Fig.3. Mean food composition of the Vistula Bay fishes during vegetation season.

Fig.4. A scheme of food relations of the Vistula Bay hydrobionts. Definitions: production: A - primary, P_z - zooplankton, P_j - plankton eating fish, P_b - benthos, P_{fb} - non-commercial benthos eating fish (pope), D - detritus; yield of fish: Y_{fp} - piscivorous, Y_{fb} - benthos-eaters. Circle - pasture food chain, rectangle - detritus food chain; broken line - value non-identified. Brackets contain kJ m^{-2}.

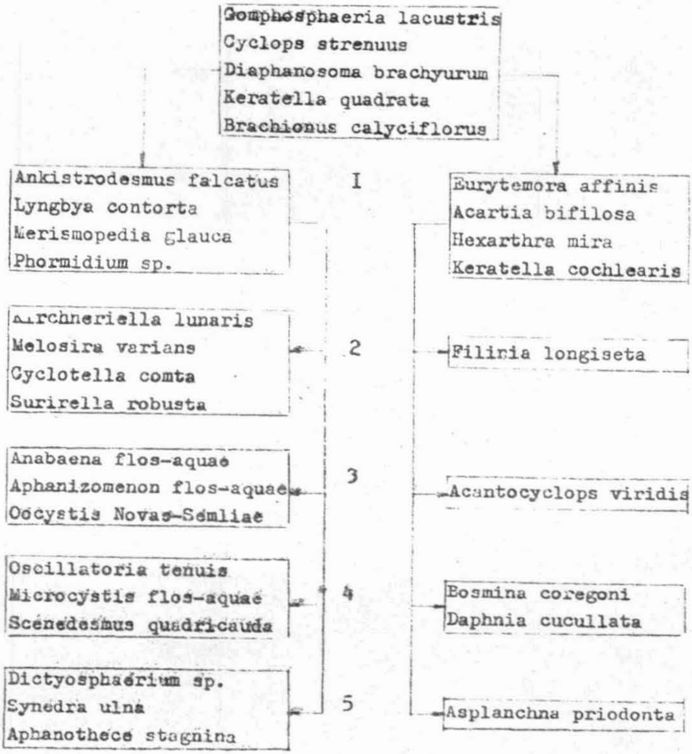
Gomphosphaeria lacustris
Cyclops strenuus
Diaphanosoma brachyurum
Keratella quadrata
Brachionus calyciflorus
Ankistrodesmus falcatus
Lyngbya contorta
Merismopedia glauca
Phormidium sp.
I
Eurytemora affinis
Acartia bifilosa
Hexarthra mira
Keratella cochlearis
Kirchneriella lunaris
Melosira varians
Cyclotella comta
Surirella robusta
2
Filinia longiseta
Anabaena flos-aquae
Aphanizomenon flos-aquae
Oocystis Novae-Semliae
3
Acantocyclops viridis
Oscillatoria tenuis
Microcystis flos-aquae
Scenedesmus quadricauda
4
Bosmina coregoni
Daphnia cucullata
Dictyosphaerium sp.
Synedra ulna
Aphanothece stagnina
5
Asplanchna priodonta

Fig. 1

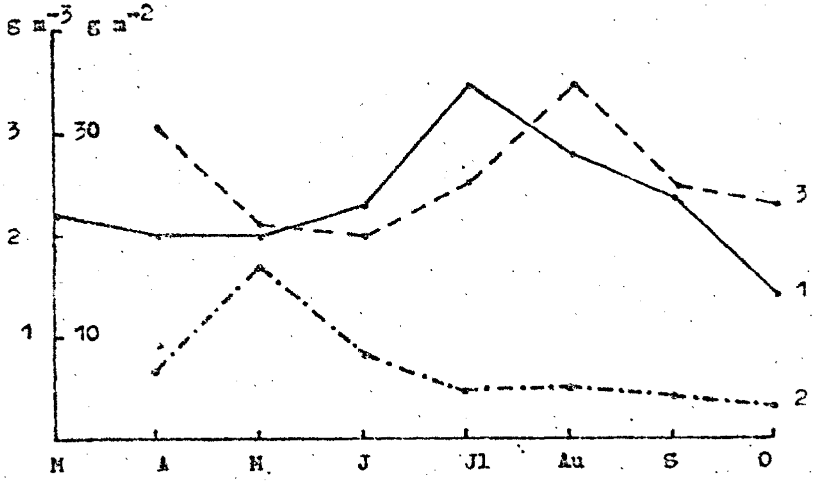

Fig. 2

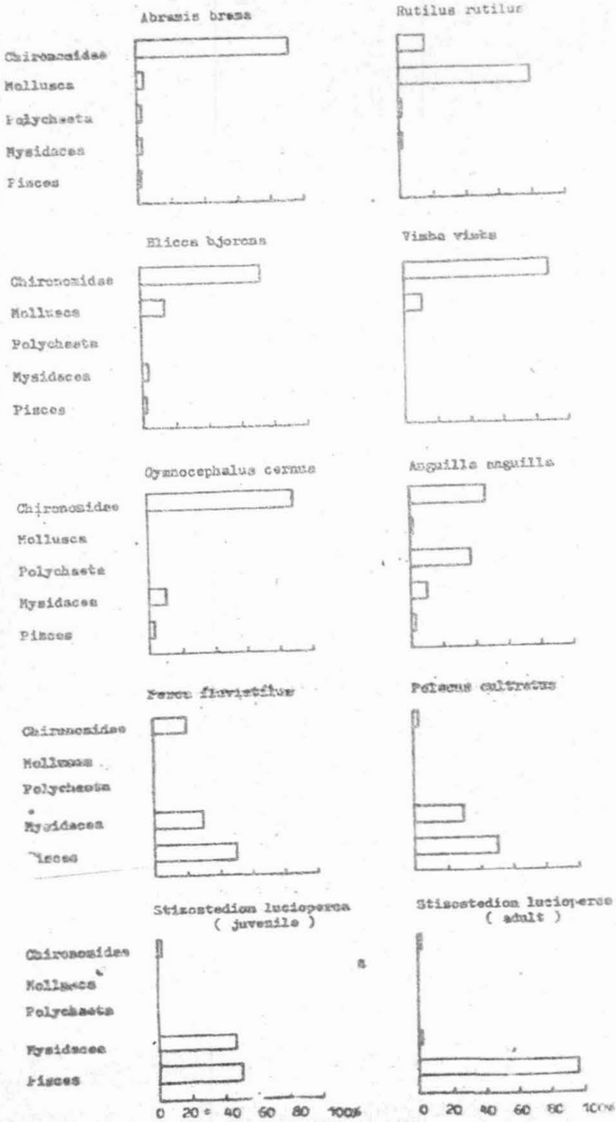
Abramis brama
Rutilus rutilus
Chironomidae
Mollusca
Polychaeta
Mysidacea
Pisces
Blicca bjorkna
Vimba vimba
Gymnocephalus cernua
Anguilla anguilla
Perca fluviatilis
Pelecus cultratus
Stizostedion lucioperca (juvenile)
Stizostedion lucioperca (adult)
0 20 40 60 80 100%

Fig. 3

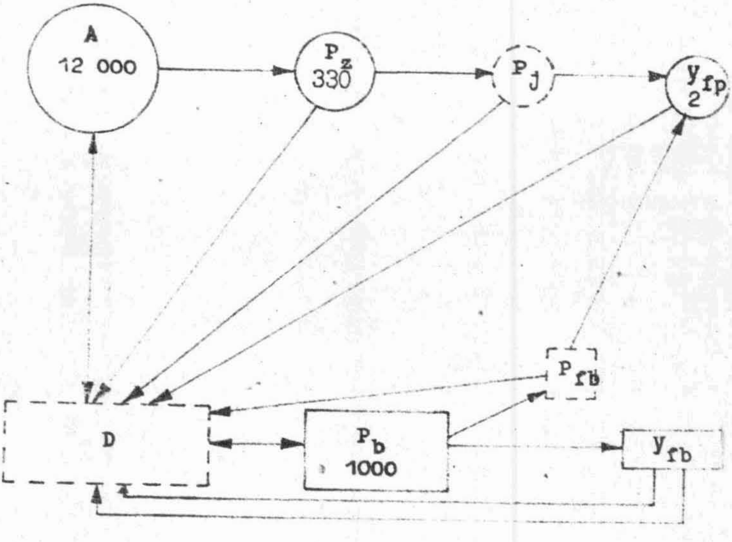

Fig. 4